Beyond 5G/6G network slicing Smart City vision

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Abstract: - Compared to the fifth generation (5G), beyond 5G (B5G) is expected to improve network capabilities by using a higher frequency band to deliver high network capacity with lower latency in order to support diverse application ranging from smart transformation and energy management to healthcare and public safety. To develop network-aware application in order to satisfy customer demands, softwarization and virtualization are the main drivers for innovation in B5G. On the other hand, 6G innovation will be driven by key technology such as artificial intelligence (AI)-native wireless and-to-end design and the continued digital-physical convergence. The transition to 6G offers an opportunity across network architecture and radio-access for improved efficiency, scalability and speed in delivering services. In the near future, the Smart City (SC) will be characterized by the reliable flow of data from inter-connected wired and wireless networks. The coming B5G allow for significant performance enhancements and the ability for mobile network operators. The process allows networks to be broken into numerous slices that can be managed independently, not affected each other. The challenges faced in Smart Cities are addressed through continuous by regulators industry, applications, network operators service/technology providers and public partnership organizations. This will allow the opportunities brought about slice technology to be maximized.

Key-Words: 5G/6G mobile networks, NS network slicing, SC smart city

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1 Introduction

To enable new emerging Smart Cities (SC) requirements, B5G services will have to provide significantly better performance than 5G. For example, a peak data rate of 1 Tbps is to 50 times higher than 5G, and air-link latency of 100 µs 1/10th of 5G. It is clear that commercialization of 5G has revealed its limited capability to support real-time services with stringent requirements, thus provide the way for research on 6G.

Network slices are all the resources, including radio access network (RAN) and core network (CN) functions, required to fulfill end-to-end services. Individual slices will have different characteristics including quality of services (QoS) and latency, while individual services will be able to access multiple slices simultaneously.

As for the requirements for network slicing (NS) frameworks, it can be summarized in way shown in Table 1, together with the corresponding function characteristics. On the other side, it is expected that there will be about 30 billion connected objects by 2030 year to support diverse applications ranging from smart transportation and energy management to healthcare and mobile safety.

Table 1. Requirements for network slicing (NS) framework and its characteristics.

Requirements	Characteristics
Resource reservation	Understands the compute and network resources are reserved as a past of initial creating during the maintenance of a slice.
Resource assurance	A network slice infrastructure which allows operators to allocate part of the network resources to meet resource characteristics.
Multi-dimensional service vertical	Refers to supporting dynamic multi-service and multitenancy.
Multi-domain coordination	Refers different technology related network domains.
Operational isolation	Each network slice may have its own operator that sees this slice as a complete network and can manage as its own.
Transparency	Facilitate creation of an isolated infrastructure for the use case over a common architecture. It provides inter-operability and a common resource.
Reliability	Important resource attribute in the type of service verticals which can not deliver functionality unless the network is reliable.

There are two reasons for a network slice needs a service:

- the service can not provide optimal experience on a best-effort network, as well as
- it is expensive and inefficient to build a separate infrastructure.

It should be noted that security considerations apply to each kind of slice using wireless technologies [2].

To develop network applications to satisfy customer demands in smart city environment, softwarization and virtualization are the main drivers for innovations in B5G. With a focus on connectivity, 6G innovation will be driven by key technology such as artificial intelligence (AI) wireless end-to-end design and continued digital-physical convergence. The transition to 6G offers an opportunity across network architecture and radio access for improved efficiency, scalability and speed in delivering services.

This work is organized as follows. At first, the motivation for B5G is emphasized. Then, smart city infrastructure, together with end-to-end network slicing is presented. Next section deals with network slicing for Internet of Things (IoT). In the second part, challenges with implementation of network slicing such as monitoring in urban environment, data collection and prioritization in green smart cities are analyzed. Network slice instances as well as research direction conclude the paper.

2 Motivations for B5G network slicing

Smart cities with network slicing technology enable coordinated effects with local government, business and the other organizations to provide convenient services for the people who live and work there. Countries are addressing issues in sectors such as energy, healthcare and security by converting fast – expanding urban areas into smart cities. 5G has been accelerated such as developments by its support for dense networks of sensors and actuators which will enable organization and individuals to monitor and control them remotely using the appropriate platforms.

Slices can be customized to each cases required performance related to entities such as capacity, latency, reliability and geographic average. This is of particular importance for smart city implementations taking into account that devices involved directly/indirectly have an impact on individual's lives.

The key performance indicators (KPIs) are to address a broader class of services which spans multiple vertical industries such as industrial IoT, autonomous vehicles, healthcare, smart grid, smart agriculture, smart home, smart cities and so on. The vertical industries are very diverse, each with different service characteristics and the performance requirements.

The main motivations for slicing are to elaborate KPIs, performance requirements use cases, real-world implementations of smart city applications, QoS guarantees. Next to develop B5G network slicing frameworks based on the corresponding design as well as to provide a technical challenges of dynamic, adaptive and internet-based network slicing, while also exploring slicing security, management and isolation within smart city use cases.

3 Smart City infrastructure with end-to-end network slicing NS

As previously stated, network slicing represents a paradigm to operate mobile systems. The underlying infrastructure is sliced into separate networks thanks to specific needs of their tenants. With a next generation wireless technologies such as network slicing, experience of large cities is enhanced. At the same time, networks are going to improve their infrastructure. High data rates 50+Mbps, extensive coverage 10+Tb/s/km2 and low latency <5ms are just a few of the target KPIs to be fulfilled by the next generation mobile network. However, not all services are going to require these KPIs, because different applications will have different requirements. Network slicing is one key technology to provide services that meet these requirements [3].

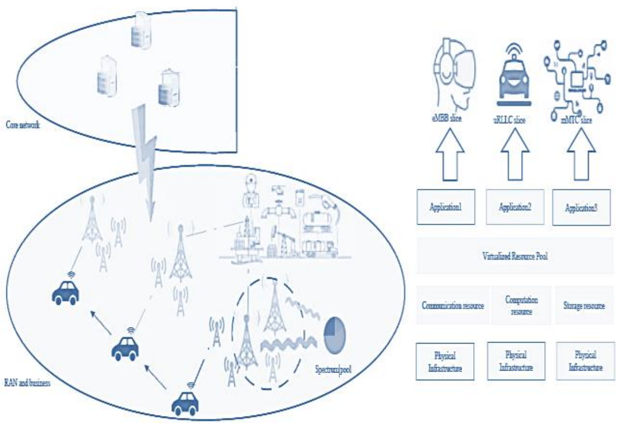

Fig. 1 An example of network slicing (NS) [4].

A typical scenario where multiple mobile network operators (MNOs) and infrastructure providers (InPs) coexist in a common place is illustrated in Fig. 1. In order to support an auto-drive applications that extends across wide area, many local MNOs and InPs from different locations will jointly provide services whenever a vehicle enters their coverage. For maintaining a shared wireless spectrum pool on the unlicensed band, multiple MNOs need to negotiate with each other for access rights to avoid interference. In building the network slicing system, cases call for cooperation between multiple MNOs and InPs. In addition, the ever increasing demand for storage and computation of end users attracts more and more cloud providers to join network slicing. Network operators can exploit network slicing not only for reducing capital and operational expedition, but also for enabling network programmability and innovation, in order to enrich the offered services from providing simple communications pipelines to a wider range of business solutions.

The general network slicing architecture comprises three functional layers: service instance layer, network slice instance layer and resource/infrastructure layer as shown in Fig.2. service instance layer provides business and user services, which may be provided by network providers.

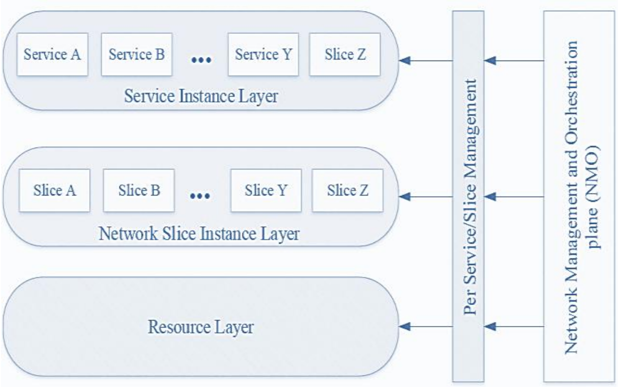

Fig. 2 General network slicing (NS) architecture with functional layers.

Network slice instance layer is responsible for creativity and managing network slices based on the requests from the application layer. The resource/infrastructure layer is responsible for providing and managing physical and virtual network resources such as connectivity, computing and storage. The network slice controller/orchestration interfaces with each layer in the network slicing architecture to coherently manage and coordinate these diverse functionalities effectively.

4 Role of B5G network slicing NS

Network slicing and softwarization technologies play a significant role in enhancing the efficiency and flexibility of smart cities. By allocating dedicated network resources to each slice, network slicing enables the required communication services optimized for diverse smart city applications' use cases. The application of B5G network slicing in smart cities brings several benefits. First of all, it enables the coexistence of multiple smart cities with distinct characteristics on a shared communication infrastructure. It is important to emphasize that each service can have owned network slice with QoS guarantees and efficient data exchange. Next, network slicing ensures the dynamic allocation of network resources based on demand. As the communication requirements of smart cities applications can very over time, network sling allows for resource scaling and adaptation to meet changing needs. As an example, it should be noted that during peak demands periods, it is possible to allocate additional network resources in order to make possible uninterrupted data transmission and control actions.

Softwarization technology, such as software defined networking (SDN) and network function virtualization (NFV) are components of network slicing for smart cities applications. The function of SDN is to separate the control plane from the data plane. In this way, the centralized control enables efficient orchestration of network resources, simplifies network management while QoS polices are based on user requirements. On the other hand, NFV virtualizes network functions and deploys them as software instances on hardware. By deploying network functions dedicated hardware applications, NFV offers flexibility and scalability in deploying and managing network services. This reduces the reliance on specialized hardware, simplified network maintenance, responding to changing demand. The combination of network slicing, SDN and NFV for support of smart cities applications results in a more agile and adaptable communication infrastructure. B5G network slicing and softwarization technologies are crucial enables for the evolution of smart cities applications toward more intelligent, resilient, and automated smart cities applications management.

The network slicing framework requirements for smart cities applications are shown in Table 2, together with the corresponding references.

Table 2. The network slices framework and the corresponding references.

	NS	References
1.	Isolation	[5]
2.	Security	[6]
3.	Resource utilization	[6], [7]
4.	Sharing	[8]
5.	scalability	[9]

Designing B5G network slicing framework requires a comprehensive approach that takes into account elements to ensure that as a result it is possible to obtain flexible, scalable, efficient and secure B5G network slicing.

The emergence of 6G communication technologies brings both opportunities and challenges in smart cities. It is expected that the 6G communication era will begin in 2030. Combining digital intelligence with urban infrastructure in order to improve efficiency, sustainability and quality of life is the next step towards the wireless era [10]. The combination of 6G with network slicing is a power force that has the potential to develop more and more communication infrastructure. The incorporation of 6G and network slicing offers the potential for a communication network that is not only efficient and resilient but also capable of scaling and adopting to the changing requirements of urban areas. The rapid advancement for communication technologies specifically the shift from B5G to 6G offers a chance to include the Internet of Things (IoT) in smart cities. Network slicing is a critical factor in improving this integration.

5 Internet of Things and network slicing NS in smart cities SC

The emergence of 6G communication technologies brings both opportunities and challenges for the IoT in smart city which consists of a diversity of public utility and vertical industry services with extremely different performance requirements. Network slicing as a key technology to provide distant vertical networks and differentiated QoS guarantees in a shared infrastructure is of great significance. Thus, it is necessary to apply network slicing for IoT in smart city [11]. People worldwide are carrying out their future to build smart cities, where utility infrastructure and public assets in every corner of the cities are connected through IoT infrastructure, enabling guarantees and utility service provider to make decisions for improved citizen services [12]. The efficient connectivity in the widely deploy devices has become the basis for building smart cities. IoT solutions in smart cities scenarios together with the service providers have to deploy sensors to gain more detailed information and computing facilities as close as possible, gaining in sights from gathered information. The concept of network slicing through using the same network infrastructure can be divided into logically independent networks called network slice instances (NSIs). Data flows of similar service characteristics can be aggregated in the same slice instance with a designed set of network resources to reduce resource-scheduling complexity. Moreover, network slicing ensures isolation between slice instances which is a prerequisite for some holders in smart city. Another driving factors of network slicing lies in improving the efficiency of network management. To serve smart city and meet the broadband demands of companies on customized IoT networks many slice instances will be subscribed to and simultaneously running on the same network infrastructure, with an appointed service level agreement. The process is agile demands from tenants can be accomplished. At the same time, machine learning (ML) approaches are widely used to understand the behavior of practical systems.

As an example, network slicing for IoT applications in smart city is shown in Figure 3.

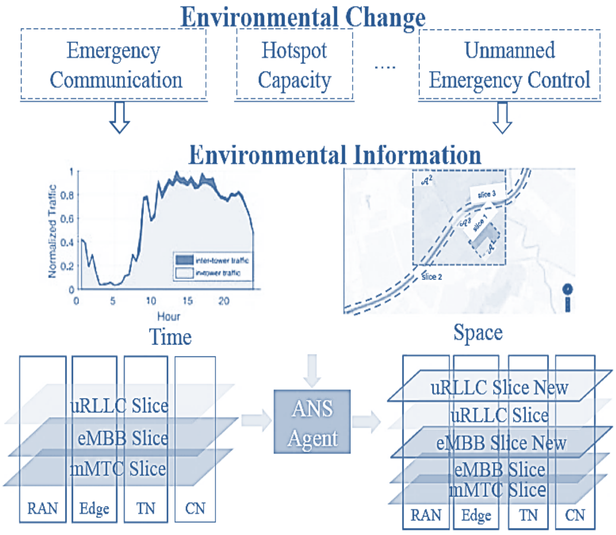

Fig. 3 Smart city with network slicing (NS) for IoT applications [11].

Network services of emergency communication, hot spots capacity entertainment, and so on, cause network environment changes, which will be reflected in the spatial and temporal traffic distribution of slice instances and the network performance indicators. The automatic network slicing (ANS) agent, following the deep reinforcement learning (RF) framework, will gain experience in taking better network slicing actions.

Smart IoT devices have attracted a lot of attention a few years ago for critical applications where edge computing solves latency issues associated with the cloud, as real-time data is pre-processed closer ti the user. Along with reduced latency and with machine learning, the IoT edge architecture brings enhanced safety/privacy. AI/ML techniques used in IoT edge applications have shown great advantages in mitigating the resource constraints exhibited by IoT devices and necessitating their inclusion to many smart city design applications. This can allow IoT edge devices understand and make predictions based on the data they store and process. On the other hand, even where relatively small data is available, IoT edge can be predict/decide on matters that impact human safety was better, keeping citizens and infrastructure safer and reliable.

6 Implementation network slicing NS

In order to cope with different requirements, the concept of network slicing has been proposed as a means of providing better resource isolation and increased statistical multiplexing [13]. The next generation mobile network alliance NGMNA defined a network slicing as a concept for running multiple logical networks as independent business operators on a common physical infrastructure. Each network slice represents an independent virtualized end-to-end network and allows operator to run difficult deployment s based on different architectures in parallel. A network slice as a logical end-to-end construct is self-contained, having customized functions also including those in the user equipment (UE), and using network function chain for delivering services to a given group of devices.

AI and cognitive computing are two corner-stone technologies that enable smart cities to enhance the quality and performance of urban services. To large-scale cyber system operates such as, for example, smart cities and safe community system are enabling high density deployment of a number of IoT device. Also, cognitive IoT enabling computing and fog computing are playing erased node in implementing the spectrum management capabilities in ensuring the success of smart cities systems.

6.1 Monitoring in urban environment

Urban monitoring environment information such as spatial-temporal changes, crowed distribution, pollution and so on, can be used for improving urban sources and city's sustainability [14]. IoT technology is promising for efficient urban environment monitoring in smart cities [15]. A large number of sensors can be applied to called environmental information, for example air platform and traffic. All data are gathered and analyzed the enable various services: smart home, traffic control, pollution evolution, smart grid [16].

IoT-based urban environment monitoring is challenging due to the same reasons. First of all, as cities grow, the monitoring region becomes leader. This requires large-scale monitoring systems. Some research efforts on building large scale sensor network exist achieving urban environment monitoring requirements. Secondly, an urban environment is complex in geography with streets, buildings, parks, rivers, lakes etc. It should be added that some applications need to monitor crowd distribution and traffic which leads to improving and designing better transportation systems. Also of huge importance is the evaluation the level of solutions as well as the water quality monitoring [17]. As an example using heterogeneous unmanned vehicles to address the challenges of urban environmental monitoring is shown in Figure 4.

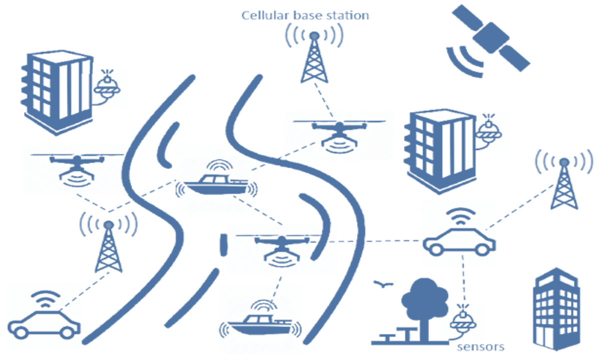

Fig. 4 Vehicles for urban environment monitoring in Smart Cities [18].

The vehicles include ground vehicles, air vehicles (drones) and water vehicle (unmanned boats). This can cover almost all regions within the city. Ground vehicles are powered by fuel or large batteries, so they can work during all time monitoring. Air vehicles have limits energy but with strong moving capability. They are preferred for the monitoring of a large area. Water vehicle can work in rivers and lake performing task like water pollution monitoring. It is if interest to emphasize that these vehicles can work collaboratively to achieve large scale comprehensive urban environmental monitoring. Here, it is if interest how to efficiently assign tasks to heterogeneous vehicles in order to maximize monitoring quality while minimizing the cost. Vehicle collaboration relies on efficient network connection among them. This network should have low delay, so that vehicles can quickly share their status information and respond to collaboration requests [18].

6.2 Management and orchestration

Management and orchestration (MANO) handles the dynamic management of network slices order to run and adapt complex slices required by tenants i.e., enterprises, such as smart cities applications service provider that places slice requests to the mobile network operator responsible for network slicing.

MANO is a critical component of the B5G/6G network slicing framework for smart cities applications. It is responsible for managing the entire life-cycle of network slices, including creation, institution and termination. The MANO provides capabilities for slice life-cycle management, resource management, service assurance, security and interoperability. The final goal is to ensure continual and successful deployment as well as operation of network slices for smart cities applications.

6.3 Prioritization in green Smart Cites

Data prioritization (DP) is a technique that produces a condensed form of the original data by analyzing its contents. DP studies are concerned with data collected through capturing devices or focused on prioritization of data of certain type such as, for example, surveillance or industry and so on. This leads to the need for DP tolls that intelligently and cost-effectively prioritize a large variety of data for detecting events and effectively manage them, making at the same time the smart cities greener. Data analysis techniques need to be applied to filter and store significant data for the future use. Considering these challenges, a green approach to intelligent data collection and prioritization is urgently required in smart cities to help them become greener [19]. This procedure can help in the selection of a suitable view for sensing usual data in surveillance that consists of multiple sensors connected via IoT infrastructure. As for data interest, they will be processed in real-time. The function of surveillance decision marks is facilitated producing cost-effective services for green smart cities. To achieve thee goals an energy efficient and intelligent DP framework for a smart city is proposed in Figure 5.

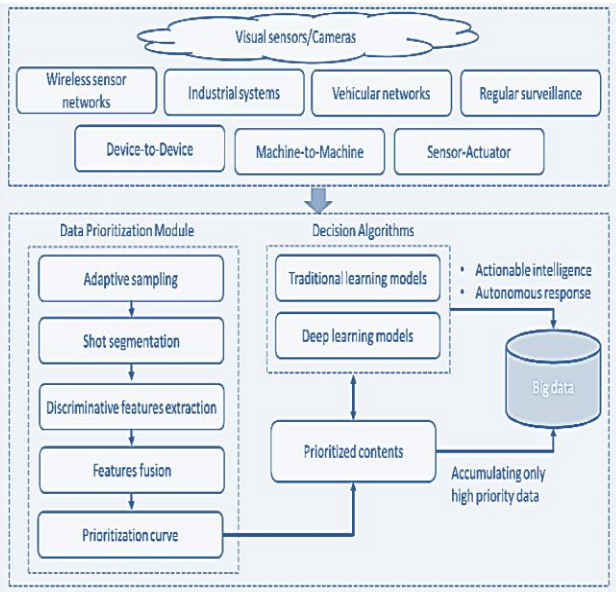

Fig. 5 Architecture for intelligent data prioritization [20].

In smart cities a significant number of sensing devices collect data from various sources. Visual sensors are one of the major usual data collection services producing a large number data [20]. The energy and bandwidth constraints limit the processing of such huge-sized data. Thus, only prioritized data needs to be stored for the analysis. Also, sending through large volumes of data for required information is time consuming and inefficient. To address these issues, a data prioritization framework for autonomous collection of visual data is proposed. Academia and industry have shown significant interest in green smart cities. The focus is on their different aspects such as DP, security, interoperability and communication. Also, there is an interest in investing, funding and researching in different aspects of green smart cities. To cover all important contents in the collected data with minimal redundancy and computational efficiency, DP should be considered as a multi objective optimization problem. With this approach events can be detected more effectively, while considering the processing and power constraints of IoT devices in green smart cities.

7 Concluding remarks

Network slicing (NS) has evolved from a simple fixed network overlay concept to a feature of emerging multi-provider 5G/6G systems that will enable new business opportunities by facilitating flexible and agile support for multi-service and multi-tenancy. Key network slicing scenario in Smart Cities worldwide adopted are addressed through continuous considerations by regulators, industry, associations, network operators, service/technology providers and public-private partnership organizations.

Challenges such as slice isolation, security, orchestration, interoperability need to be addressed to fully realize the potential of B5G network slicing in smart cities. Ongoing research and development efforts are crucial for further design, implementation and deployment.

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